

1998

**Developments in self escape and aided rescue arising for the Moura No.2
Wardens Inquiry - A Special Report by the Joint Coal Industry Committee
from Queensland and New South Wales**

M. Jakeman
Capricorn Coal

Follow this and additional works at: <https://ro.uow.edu.au/coal>

Recommended Citation

M. Jakeman, Developments in self escape and aided rescue arising for the Moura No.2 Wardens Inquiry - A Special Report by the Joint Coal Industry Committee from Queensland and New South Wales, in Naj Aziz and Bob Kininmonth (eds.), Proceedings of the 1998 Coal Operators' Conference, Mining Engineering, University of Wollongong, 18-20 February 2019
<https://ro.uow.edu.au/coal/229>

**Developments in Self Escape and Aided Rescue Arising from
the Moura No. 2 Wardens Inquiry**

A SPECIAL REPORT

by

Joint Coal Industry Committee from Queensland and New South Wales

**Chairman – Mitch Jakeman, Capricorn Coal
Tel: 07 49850202 Fax: FAX 07 49857708**

Developments in Self Escape and Aided Rescue Arising from the Moura No. 2 Wardens Inquiry

Chairman of Strategy Development Committee

Mitch Jakeman
General Manager, Capricorn Coal

Self Escape

Roger Bancroft
Senior Inspector, DME QLD
Glynn McDonald
Senior Inspector, DMR NSW

Communications

Bruce Robertson
Chief Mining Engineer, Shell Coal

Gas Management

Paul McKenzie-Wood
Manager Technical, NSW Mines Rescue

Aided Rescue

Tony Sellars
Manager, QLD Mines Rescue

Incident Management

Gary Gibson
Chief Executive Officer, NSW Mines Rescue

Training

John Sargaison
Queensland Minerals Council

Task Group 4 Members and Contributors

Mr Mitch Jakeman (Chairman)	Capricorn Coal
Mr John Sargaison (Secretary)	QMC
Mr Bruce Robertson	Shell Coal Ltd
Mr Brian Lyne	DME, Qld
Mr Roger Bancroft	DME, Qld
Mr Bruce McKenzie	DMR, NSW
Mr Terry Abbott	DMR, NSW
Mr Bill Allison	CFMEU
Mr Jack Tapp	CFMEU
Dr Cliff Mallett	CSIRO
Mr Roger Wischusen	AMIRA
Mr Tony Sellars	Qld Mines Rescue
Mr Gary Gibson	NSW Mines Rescue
Mr Paul Mckenzie-Wood	NSW Mines Rescue
Dr Chris Rawling (former Chairman)	QCT Resources

Table of Contents

Page No.

FOREWORD

EXECUTIVE SUMMARY AND RECOMMENDATIONS

724

Self escape

724

Communication introduction

724

Gas management

725

Aided rescue

725

INTRODUCTION

OBJECTIVES

SCOPE

DEVELOPMENT OF STRATEGY

SELF ESCAPE - EMERGENCY ESCAPE SYSTEMS

732

Introduction

732

Escape strategy

732

Early warning

733

Communications

734

Escapeways

734

Guidance systems

735

Change-over stations

735

Refuge chambers

735

Training

736

Evacuation management plan

736

Bibliography

736

COMMUNICATIONS - RESEARCH AND DEVELOPMENT PROJECTS

GAS MANAGEMENT GUIDELINES

739

Introduction

739

Terms of reference

739

AIDED RESCUE

747

Introduction

747

Terms of reference

747

Refuge chambers used in underground mining

747

MICROSEISMIC DETECTION SYSTEMS

749

Introduction

749

The MSHA seismic location system	749
MICROSEISMIC APPLICATION FOR AUSTRALIA	750
Large diameter drilling	752
Rescue emergency vehicle	752
Introduction incident management	753

FOREWORD

Although the coal industry in Australia continues to expand and chase improvements in technology, equipment, training and safety, the industry still suffers from underground incidents which have tragic consequences for individuals and families. The responsibility is for all stakeholders, employers, employees and support agencies to remove causes and behaviors which create such incidents. This will make underground coal mining safer for all personnel.

The fundamental mind set to safety performance has changed dramatically over the last 15 years. During the early 1980's, the recognition was made that the industry safety performance was very poor. At the end of that decade and by the early 1990's many large companies, together with government and the unions were supporting safety training programs to reduce Lost Time Injuries - the high level measure of safety. These programs produced varying levels of success, but developed a scepticism amongst some parts of the industry where the results were managed, not the risks.

A few incidents occurred in the early to mid 1990's which showed that the rate of change and the approaches to the management of safety were not good enough. The industry started to look at Risk Management and the need to formally quantify the risks, controls and protection to improve safety performance.

The Wardens Inquiry into the accident at Moura No. 2 in 1994 highlighted the need to review rescue operations for persons underground.

A coal industry committee, already set up to review the fundamentals of coal mines rescue, was given the task to review escape and rescue options by the Queensland Chief Inspector of Coal Mines. The committee consisted of a broad cross section of major stakeholders of the NSW and Queensland coal industry. The process of review was fundamental, exhaustive and widespread in its scope. It was clearly appreciated by all the committee members that escape and rescue options for mine personnel could be substantially updated and improved. The mind set previously held, That mines rescue was the calvary charging over the will to rescue people, needed to be changed in response to recent major incidents. This change would encompass the techniques, equipment, design of mines and the role of the rescue service.

The work has taken 2.5 years to get to this stage and will require the stakeholders in this industry to implement the recommendations, complete R and D projects and participate in the information sharing that will be necessary to sustain these improvements. I would like to thank all those who have contributed including the sub committee participants. The active involvement, participation and dedication of everyone, has recognised only the need to improve safety without the barriers of state, political or industrial interference. It is encouraging to know that we can work together for the common good when the need is greatest.

Mitch Jakeman
Chairman of Task Group 4
Developments in Self Escape and Aided Rescue

EXECUTIVE SUMMARY AND RECOMMENDATIONS

The inquiry into the 1994 accident at Moura No. 2 Colliery included in its findings that mine escape and rescue options for persons in underground coal mines were in need of review. It recommended the establishment of industry working groups to report to the Chief Inspector of Coal Mines (Qld) on matters including escape strategy and life support for escape from mines.

Task Group No. 4, comprising industry stakeholders from Qld and NSW, has examined issues relevant to escape and rescue from Australian underground coal mines and formulated recommendations and guidelines in response to the set objectives and scope.

With regard to existing practice it was determined that:

- for persons underground at the time of a major incident, escape options are limited and there is no consistent strategy in place for rescue of mineworkers across the industry
- filter self rescuers have a limited application in mine emergencies
- knowledge of conditions underground after an accident is insufficient for accurate assessment of the mine environment
- rescue strategies require upgrading

The diversity of mine configurations and potential emergency scenarios led the Task Group to determine six (6) critical issues:

Self escape

There is a primary need to enhance the capabilities of underground persons to effect their own rescue - ie "self escape". This is to be achieved by the provision of facilities in mines, training of mineworkers and management and the development of generic and mine-specific escape strategies.

Escape routes, alternative routes and facilities are to be planned, developed and equipped as part of Self Escape Management Plans. An oxygen-based escape system is required with the following attributes:

- all persons to wear self contained self rescuers;
- replacement SCSR caches provided at suitably located changeover stations; and
- use of refuge chambers where appropriate.

Communication introduction

A generic strategy is required to establish the location and condition of persons underground after an incident and to maintain communication during aided rescue. The key areas requiring development are:

- guidance systems for self rescue;
- communications post incident; and
- determination of status of all personnel underground after an incident.

These will require technology transfer and some research. An industry expert committee has been formed to champion these initiatives.

Gas management

Gas management guidelines are established for effective and safe incident control. This should look at the design and location of monitoring systems, the integrity and interpretation of information, mines rescue requirements for both underground and to the surface and the training/competency of people and systems.

Aided rescue

There is also scope for intervention, assistance and rescue of underground persons by surface personnel, i.e. - "**aided rescue**". However, significant changes to rescue strategies are required in order to make use of modern technology to increase the chances of successful aided rescue. The determination of the status of conditions and personnel underground are key areas requiring improvement. Rescue options and post incident control strategies need to be appropriate for the incident.

Areas that need to be researched and developed are a new mines rescue vehicle, consideration of large diameter boreholes for rescue where appropriate, and the upgrade of environmental monitoring and communications equipment needed for rescue teams.

Aided Rescue Management Plans are required at mines to ensure that a coordinated and effectively-resourced rescue response can be mounted in order to maximise the chances of saving persons trapped in a mine. Plans should address:

- means to establish and monitor the status of persons underground;
- means to establish, monitor and assess conditions in the mine;
- establishing post-incident controls;
- rescue options; and
- training for aided rescue

There is a clear need for the mines rescue services to revise their operating strategies and infrastructure to accommodate the new ways of aiding rescue proposed by this report.

Incident management

Provision of new escape and rescue systems will be of limited value unless the people in danger or participating in rescue can make the appropriate decisions when confronted with an emergency situation. Planning, preparation and training for such emergencies is essential to improving their chances of survival.

Incident Management allows those managing the incident to follow decision criteria to minimise risk and conduct a successful emergency.

Training developments

Every underground mine should develop a Self Escape Management Plan as part of a Safety Management Plan to provide all persons underground with the capability to reach a place of safety, recognising the difficult environmental conditions following an incident. Training initiatives in the form of new generic training resources and training guidelines should be developed to support the use of these plans.

Specific recommendations aimed at improving capabilities in these six critical areas have been made. These recommendations promote the Task Group's proposed vision for response to incidents at mines in the future:

All persons underground at the time of an incident shall be trained, equipped and able to make an escape to the surface, or place of safety, if physically capable. Monitoring, communications systems and other new rescue technology will provide surface personnel with the capability to safely deploy aided rescue measures to rescue those unable to self-escape.

Further development, prioritisation, management and funding of initiatives in this area require the continued involvement of industry stakeholders. At the end of 1996 there were several urgent initiatives that could be quickly implemented by industry to bring about improvements in emergency escape and rescue.

The specific recommendations of the Moura No. 2 Warden's Report Implementation, Task Group 4 Report (1996) are listed below.

Recommendation 1

Every underground mine should develop a Self Escape Management Plan and an Aided Rescue Management Plan. The interrelationship between the Escape and Rescue Plans must be examined and incorporated into the Mine Safety Management Plan.

Recommendation 2

- a) A generic industry training resource package for self escape and aided rescue should be developed.
- b) Guidelines for mine specific training in self escape and aided rescue should be developed.

Recommendation 3

Every underground mine should establish an escapeway from all parts of the mine to the surface or to an alternative place of safety. A detailed risk analysis of proposed escapeways will need to be undertaken and strategies developed to control risks.

Recommendation 4

From each part of every underground mine, there should be at least one route, other than an escapeway, which enable self escape to the surface or an alternative place of safety. A conveyor roadway or a return roadway are not precluded for this purpose.

Recommendation 5

An oxygen-based self escape system should be provided for all persons underground.

Recommendation 6

Each person underground should be equipped with, and carry on their person at all times, a self contained self rescuer (SCSR).

Recommendation 7

An industry committee/forum (technical experts and operators) should be established to coordinate the advancement of capabilities to alert, to communicate with, and to assess the status of underground persons during a mine emergency.

Recommendation 8

Fixed tube bundles and gas chromatographs should be made available at all mines as the primary method of measuring post incident mine atmospheric conditions.

Recommendation 9

Research into the development of robust telemetric sensors for gas analysis and other environmental parameters, over the ranges existing after incidents, should be prioritised.

Recommendation 10

A mine emergency reconnaissance vehicle should be made available for all mines for use in emergencies.

Recommendation 11

Both pre-installed and post-incident boreholes should be considered when developing Aided Rescue Management Plans.

Recommendation 12

Rescue teams should be provided with state of the art environmental monitoring equipment and on-line communications

Recommendation 13

Equipment should be made available to ascertain the physical status of the mine environment (including temperature, humidity, pressure etc) using boreholes, and reconnaissance vehicles.

Recommendation 14

A demonstration of the capabilities of microseismic monitoring technology to detect, locate and monitor roof falls, outbursts and fires should be carried out.

Recommendation 15

The capability to model ventilation and the mine environment following an incident should be available at mines.

Recommendation 16

Guidelines, common to both Qld and NSW, should be developed for integrated emergency preparedness involving mine operators and emergency services.

Recommendation 17

Industry should develop an effective computer-based emergency decision support system for incident management and training.

Recommendation 18

A steering committee should be established to encourage and oversee the development of emergency rescue vehicles.

Recommendation 19

Mines should consider the need for refuge chambers when developing Self Escape and Aided Rescue Management Plans.

Recommendation 20

Aided rescue using shafts and/or large diameter boreholes should be considered for inclusion in mines Aided Rescue Management Plans where viable.

Recommendation 21

- A generic industry training resource package for self escape and aided rescue should be developed for mineworkers and management/others.

Status of Recommendations - 1 January 1998.

Recommendation 1	Legislated
Recommendation 2a, 2b	Likely to be a six month development process during 1998.
Recommendation 3	Accommodated within each mine's emergency evacuation hazard management plan
Recommendation 4	Accommodated within each mine's emergency evacuation hazard management plan.
Recommendation 5	Legislated in Queensland, pending in NSW (not necessarily oxygen based).
Recommendation 6	Legislated in Queensland
Recommendation 7	Have met twice - will continue to meet
Recommendation 8	Not Legislated - chromatographs are in place at all Qld mines
Recommendation 9	Research not prioritised - mentioned in gas management guidelines - requires further thought for promoting research
Recommendation 10	In place - NUMBAT
Recommendation 11	Guidelines
Recommendation 12	Dealt with in gas management guidelines
Recommendation 13	Reconnaissance vehicle - work proceeding - borehole equipment available for purchase
Recommendation 14	Research planned
Recommendation 15	Needs to be proactively energised - C. Mallet to follow up
Recommendation 16	Guidelines are being developed
Recommendation 17	Recommendations for RandD are being developed
Recommendation 18	Done
Recommendation 19	Done
Recommendation 20	In progress
Recommendation 21a, 21b	Six month project for development 1998.

In conclusion, many of these recommendation have been actioned throughout the industry through legislative amendments, the development of Safety Mangement Plans, changes to the Mines Rescue Services and further development of research projects. The aim is to continue our focus on Risk Management and not become complacent with improving results. The potential risks in mining like mother nature are unforgiving and severely penalise those that become neglectful.

INTRODUCTION

The Warden's Inquiry into the Moura No. 2 incident contained a number of findings and recommendations aimed at reducing the likelihood of future accidents. Some of the recommendations called for further investigation, analysis and the development of safe operating guidelines. Several Task Groups, representing various industry stakeholders, were subsequently assembled comprising members with relevant experience and skills to determine the required guidelines and report back to the Chief Inspector of Coal Mines (Qld).

Five such Task Groups were convened, with Task Group No. 4 allotted the task of developing guidelines in response to Recommendations 9 and 10 of the Warden's Report. These related to the development of an Escape Strategy for persons involved in an incident.

An industry panel with suitable membership had been previously formed to develop and industry plan for enhanced mines rescue following an industry forum which considered the future of the "NUMBAT" remote underground reconnaissance vehicle. This committee was allotted the additional specific tasks required of Task Group No. 4.

This report presents the recommendations of Task Group No. 4 for consideration by the Chief Inspector, and the industry in general.

OBJECTIVES

The specific objectives for Task Group No. 4 were:

1. To recommend guidelines to the Chief Inspector of Coal Mines (Qld) on self rescue escape;
2. To present a report to the Chief Inspector of Coal Mines (Qld) addressing issues identified in Recommendations 9 and 10 of the Moura No. 2 Wardens Report.

These recommendations were as follows:

Recommendation 9

"..... it is recommended that a representative industry working party, containing appropriate expertise, be convened by the Chief Inspector of Coal Mines and that group be charged with the development of guidelines for the industry covering life support for escape."

Recommendation 10

"it is recommended that the Chief Inspector of Coal Mines set up a working party, comprising persons with appropriate knowledge and experience, to examine and report on a range of issues relating to emergency escape facilities.

The group should investigate means whereby persons in any part of a mine, who are subject to disorientation or severely impaired visibility, are able to find their way out of the mine. Consideration should also be given by the group to the potential role for motorised transport in emergency escape arrangements."

SCOPE

The scope of the study by Task Group No. 4 was established as follows:

1. to develop a strategy for enhancing emergency escape and rescue for personnel with respect to the hazards associated with fires, explosions and explosive/irrespirable atmospheres in coal mines;

2. to develop guidelines for the establishment and use at underground coal mines of an appropriate self escape system from all underground work areas which is independent of external or mechanised emergency support systems;
3. to develop recommendations leading to an effective aided rescue system for underground coal mines;
to prepare a report addressing issues identified in Recommendations 9 and 10 of the Moura No. 2 Warden's Report, for presentation to the Chief Inspector of Coal Mines (Qld), by 28 June, 1996.
5. prepare a report to develop guidelines for self escape, gas management, incident management and establish training competencies and establish research projects for communication and aided rescue by Jan 1, 1998.

The report is to address a broad range of issues relating to emergency escape facilities at a coal mine. Subjects to be addressed should include:

- assistance to visually impaired or disoriented person;
- potential for powered emergency transport
- use of large diameter drill holes and possible emergency recovery routes
- rescue chambers or self contained life support refuges;
- use of designated escapeways as part of the mine design;
- communications options to determine the status of person underground
- identification of any limitations on the dimensions and operating range of emergency vehicles
- identification of the maximum distance an emergency vehicle may have to travel in any Queensland underground coal mine (currently operating) within the next 15 years.

The committee's focus spans from immediately after the initiation of an emergency incident up until the time that all personnel have been recovered from the mine, or when the emergency control team has determined that the emergency is over. The retrieval of any bodies, obtaining of evidence or recovering the mine are not considered emergency activities and should be conducted as a pre-planned operation using a risk management approach.

DEVELOPMENT OF STRATEGY

The Task Group has considered the post incident response issues in the context of the structure illustrated in the flow chart below (Fig 5.1). This flowchart tracks the development of an emergency from the incident until the mine returns to operational status or closure. It also recognises that in order to effectively prepare for incident response, management plans, rescue facilities and training need to be put in place. The critical elements of this process studied by the Task Group are the Self Escape and Aided Rescue components as well as aspects of pre-incident preparation.

Table 4. illustrates the core issues relevant to the development of an effective escape and rescue strategy

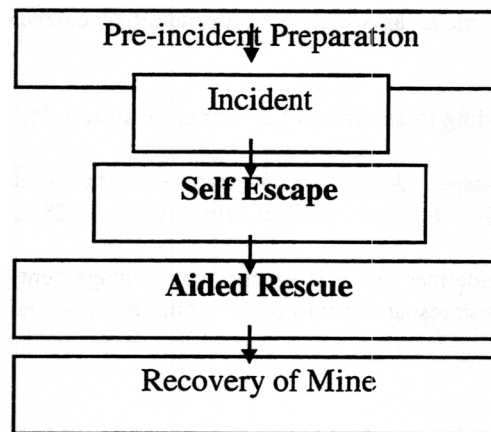


Fig 4.1 Incident Response

Table 4. Escape and Rescue Strategy - Core Issues

Self Escape		Aided Rescue		
Escape Strategy	Personnel Status	Environmental Conditions	Control Strategy	Rescue Options
Escape Guidelines	Communications	Routine monitoring	Decision Making	Equipment
Routes	Location	Post incident monitoring	Post incident management	Borehole recovery
Equipment	Condition	Reconnaissance Vehicle	infrastructure design	Re-entry
Competency		Ventilation	Sealing	Refuge Chambers
Refuge Chambers		Environment interpretation	Inertisation	Refuge Chambers
			Competency	

The issues have been broadly categorised into those covering escape strategy, personnel status, environmental conditions, control strategy and rescue options. Several of the issues overlap these categories as addressed in the detailed sections of the report. Some issues have been extensively dealt with by other task groups (e.g. seals, inertisation, re-entry) and are listed here only for completeness.

The Task Group adopted an integrated systems approach to escape and rescue which resulted in a number of recommendations which will require prioritised implementation. Several recommendations require research and development, or embody training initiatives, some require a legislative response, and most require further industry collaboration. It is recognised that until all of the elements identified are available, the recommended system may not achieve its full potential.

It was also recognised that individual mines may develop specific plans that are subsets of a total rescue system. It is therefore up to individual operations to identify, develop and implement rescue systems appropriate for their needs in conjunction with relevant stakeholders. It is vital, however that the industry adopts a uniform approach to the upgrading of escape and rescue strategies in order to maximise the potential for incident survival and response.

Strategy development was considered for current as well as future coal mine scenarios. In looking ahead, it was considered impractical to forecast the nature of coal mine layouts, size and operating environments beyond 5 to 10 years, during which time similar characteristics to those in existence today and existing mines will simply increase in area and

distance from surface entries. Some may add man-winding shafts. It is expected that escape and rescue strategies developed today will be continuously reviewed and amended to maintain relevance.

SELF ESCAPE - EMERGENCY ESCAPE SYSTEMS

Introduction

Issues relevant to self-escape from Australian underground coalmines have been examined and recommendations and guidelines formulated in response to the terms of reference and scope for Task Group 4. The issues relate to the implementation of Task Group 4 recommendations 1, 2a, 3, 4, 5, 6, 19, 21a, 21b (see pp 10-12).

Self Escape - Emergency Escape Systems, covers the major points arising from the work of both the Queensland and New South Wales working groups, and the results of a study of overseas escape strategies that was undertaken by the NSW working group.

W. Barraclough, BHP Coal
R. Bancroft, Dept Minerals and Energy Qld
P. Eade, BHP Coal
G. Dwyer, United Mineworker's Union
G. Fawcett, Dept Mineral Resources
G. MacDonald, Dept of Mineral Resources
P. MacKenzie-Wood, Mines Rescue Service NSW
F. O'Connor, Appin Colliery

Escape strategy

Evaluation of the various factors involved identified a number of major elements that need to be addressed in the development of an emergency escape system that enables persons to escape safely.

Some of these elements are:

- Early Warning;
- Self Rescue Apparatus;
- Communications;
- Guidance Systems / Lifelines;
- Escapeways / Transport;
- Refuge Chambers / Changeover Stations;
- Training of personnel; and
- Safety Management Plan for Evacuation.

The escape of persons underground will be enhanced by the use of a planned strategy that has been developed by consideration of these elements and recognition of the potentially difficult circumstances a person could encounter following an incident. Importantly the strategy will include the realisation that the mobilisation of rescue personnel could take time. The initial reactions of persons underground to an incident situation are a significant determinant on their survival. Planning, preparation and training for such emergencies are essential components required to improving their likelihood of survival.

Early warning

The role of an early warning system is to sense the first signs of fire or explosion and communicate an alarm so that evacuation of the mine or part can take place. Control measures taken at the earliest possible time would allow egress through reasonably smoke free escapeways and maximise effective escape.

Carbon Monoxide and smoke sensing systems offer considerable potential for early and more reliable fire detection than do other available systems.

A control system must be established to receive and analyse data on the underground environment. The system must include decision making protocols and enable control to be maintained and action to be coordinated during an emergency.

Consideration should be given to the incorporation of a communication system throughout the mine that can be used to immediately notify underground employees in all areas of the mine of the need to evacuate. The system should have the ability to provide employees with incident details and directions. Principal systems include telephone, traditional two-way radio, ground induction and leaky feeders.

Western Australian, Canadian and Mount Isa Mines metalliferous mines have introduced systems to release stench gas to the ventilation system to initiate emergency procedures.

Computer generated emergency alert systems are available where recorded messages can be transmitted to localities on an "at risk" basis. The Revmaux (HBL) mine in France utilises such a system with a maximum of 10 localities alerted at one time. An alert immediately triggers the escape procedure. A similar type of system has been used in a Queensland colliery.

The Personal Emergency Device referred to as "PED through the earth system" is capable of sending radio messages from the surface to wearers of receiving units on a mine-wide basis after an incident. The PED's utility is limited by the inability to return signals from the wearer to the surface. Medium frequency partially inductive systems (eg Rimtech, Taiheiyō) provide increased potential for survival after an incident because of the robust nature of the wave carriers used (pipes, cables etc.). Prototype units for locating trapped miners have been developed overseas but their application is limited to short range, direct line of sight and restrictive circumstances.

Self rescuers

Filter type self rescuers were introduced into the coal mining industry in the 1960's in response to many fatalities that had arisen due to conveyor belt fires (e.g. Creswell Colliery, UK, 1950 - 80 fatalities). They are only effective where sufficient oxygen is present in the atmosphere.

The introduction of fire resistant anti-static conveyor belts, fire resistant oils, reduced use of timber supports and improved environmental monitoring technology has reduced the risk of mine fires and hence the principal reason for the use of filter type self-rescuers.

An explosion occurring in the vicinity of a working face is now the principal hazard that may require the use of a self-rescuer.

In reviewing previous explosion incidents, it was found that due to the reduced oxygen content of parts of the mine atmosphere following explosions, the use of a filter type rescuer would not have enabled persons to escape.

For this reason, it is considered essential that all persons underground be equipped with a self-contained self-rescuer (SCSR), ie a self-rescuer that provides the wearer with respirable air.

There are many brands and types of SCSR's currently available. These are mainly manufactured in either Europe, the USA or South Africa, each country having different testing and approval criteria. The only international standard currently available for the testing of chemical type (KO₂) oxygen self-rescuers is EN 401 (B.S., 1993). The testing of compressed oxygen self-rescuers in Australia is covered by AS/NZ 1716 (DMR, 1996).

Because of the differing test criteria used, and the confusion that this can create when evaluating different brands, EN 401 has been recommended as the standard for the testing of chemical oxygen SCSR's. EN 401 is being adopted until an Australian standard is developed.

Immediately following an underground mine explosion, visibility can be significantly reduced causing irritation to eyes in smoke laden atmospheres. This impairs the self-escape of persons who can become disoriented. Combined with the lack of communication, serious limitations are placed on the ability to effect escape.

South African research and experience with chemical oxygen SCSRs has shown that poor visibility and disorientation can reduce the distance traveled to 60% of that expected under normal conditions.

Many cases have been cited where persons have not been able to find their self-contained self-rescuer immediately adjacent to them (DMR, 1996).

Due to this disorientation and lack of visibility, it is essential that all people underground carry an SCSR with them at all times.

Another factor that can play a major part in the escape of persons using self-rescuers is body mass. This subject is dealt with comprehensively by Paul Mackenzie Wood in his paper "Deployment of self-contained self-rescuers in coal mines"

There is a requirement in all Australian underground coalmines for the use of approved self rescuers. The minimum requirement in NSW is for filter type self-rescuers and from January 1 1998 self-contained oxygen self-rescuers have been required in Queensland.

Communications

There is a need for a communications system that would survive an incident and provide ongoing two-way communications between escaping or trapped miners and rescue personnel on the surface. The system should be compatible with the type of self-rescue breathing apparatus to be used and the likely escape or refuge options available to survivors. As power to the mine is likely to be interrupted during an incident, self-contained battery powered backup should be integral to the system. Whilst voice is the highest priority for transfer, systems which can also transmit data and video signals should be encouraged to assist the rescue process.

The minimum coverage requirement is for a communication system to be established along escape routes.

The location and tracking of all persons (and most vehicles) in underground mines should also be considered in any escape system. Effective two-way voice communication will contribute to this requirement but more efficient electronic systems should be pursued.

Current communications systems for underground mines are limited for emergency conditions but there are commercial leaky feeder based systems which have good potential provided that transmission networks can be stiffened to survive incidents or equipoped with satisfactory redundancy. Low frequency "through the earth" technology is being researched for underground-to-surface capability. Once robust networks can be demonstrated, value-adding technology such as personnel and vehicle tracking and personnel status monitoring can be deployed. Management plans must embrace the support of such communication systems and link into emergency protocols and controls.

Escapeways

Rescue response following an incident involves a period of time that, in most circumstances, requires people underground to attempt an organised escape, rather than await rescue. In Australian collieries, the distance from the working face to the surface can be considerable, and in many cases the seam grade can be quite steep. These escape route difficulties, allied with the expected problems of disorientation and poor visibility, give rise to a requirement for a roadway to be established in each mine that meets the criteria of good trafficability.

This roadway should, as far as practicable, be capable of maintaining a respirable atmosphere that is free from fumes and airborne dust, after an explosion or fire. To achieve this, the escapeway should be an intake airway and protected from damage by being segregated from other roadways with stoppings capable of withstanding low intensity explosions.

Vehicular escape would, in most circumstances, afford the best chance of persons making a rapid escape from the mine, and escapeways should be designed to maximise the likelihood of facilitating vehicular escape, without precluding or endangering passage by foot.

Guidance systems

To assist in gaining access to escapeways, and in guiding persons along escapeways in conditions of low visibility, clear guidance systems that will survive an incident are required. Knotted ropes with directional cones fitted (lifelines) have been developed for this purpose. More recently, battery-powered guidance systems, such as the "MOSES" system in South Africa and "LEADLIGHT" in Australia incorporating directionally discriminating audible pitches and flashing LED's have been developed to provide clearer guidance. The Australian system is also developing a tracking tag system which can be integrated or stand alone to determine where personnel are in the escapeways or mine workings.

Use of the term "second means of egress" is commonly applied to return airways, with little thought being given to which is the most desirable escape route. In emergency exercises involving different scenarios, employees invariably attempted to escape via the returns, even when this may have been the most inappropriate route. The concept of "second means of egress" as the primary escape route should be replaced by the concept of an "escapeway".

Mine management should carefully consider which airway would make the most suitable escapeway. Because of the need to maintain a respirable atmosphere, the risk of fire in this roadway should be reduced to a minimum. This could be achieved by restricting the use of equipment in this roadway to those items that are either fitted with fire suppression devices, or which incorporate a fail safe system to prevent the outbreak of fire.

Change-over stations

Dependant upon the distance of the working areas from the surface and the duration of any self contained self-rescuers (SCSRs) to be carried, the provision of underground caches of SCSRs must be considered to facilitate the escape of persons to the surface. The number and separation distance between caches should be based on the assumption that the mine atmosphere is irrespirable all of the way to the surface, and that visibility throughout the mine will be very poor.

Caches installed throughout a mine should be constructed so that they are protected from the effects of low intensity explosions. Persons exchanging SCSR's should be able to do so in a safe manner. This could be accomplished by being able to exchange SCSR's in irrespirable atmospheres or by the provision of changeover stations equipped with respirable air. Consideration should also be given to equipping changeover stations with communication facilities, capable of surviving an incident, to facilitate escape co-ordination.

In addition to designated caches located at strategic locations in the mine, consideration should be given to the provision of either a cache of SCSR's or some other system of respirable air, on board personnel vehicles. There are compressed air systems now available, comprising a storage cylinders and a number of face masks connected to a common supply regulator, that could meet this need.

Refuge chambers

Refuge chambers have an accepted place in rescue strategies in South African coalmines where workers are instructed to make their way to the section refuge chamber. This is mainly due to the large areal extent of the mine workings, the generally shallow depth of workings (enabling borehole recovery in the event of a disaster) and the differing cultural backgrounds and experience of the mine workers.

The majority of opinions sought on the use of refuge chambers in Australian coalmines indicates that Australian coal miners, in the absence of incident information, would attempt to reach the mine surface rather than stay underground in a Refuge Chamber.

In the first instance, escape systems should be provided to enable persons to escape to the surface of the mine or alternative place of safety. Operators should, however, examine their own circumstances and possible scenarios to ascertain whether or not there is a place for refuge chambers in their Self Escape Management Plan.

Current thinking indicates that it is very unlikely that rescue teams will be sent into a mine with explosive or toxic concentrations of gas, and that miners will generally need to effect their own rescue.

For this reason it is believed that regardless of whether a Refuge Chamber or a Change Over Station is used, the system should be mainly designed so that miners have a safe place to assemble.

The Refuge Chamber or Change Over Station should preferably be supplied with a respirable atmosphere and means of communication to the surface so that people can plan their escape and change from one self rescuer to another in safety.

While the system may be best designed to provide assistance to a safe and timely escape, it needs to be recognised that there may be injured persons that are unable to escape from the mine, but may be able to reach a place of safety if one is provided.

Training

Provision of oxygen self-rescuers, early warning systems and escapeways will be of limited value unless the people attempting escape can make the appropriate decisions when confronted with an emergency situation. It is essential that all mineworkers be given adequate and regular training in all aspects of the mine escape system.

Training exercises should entail more than just travelling through the second means of egress or escapeway.

A feature of both USA and South African mineworker training is participation in regular evacuation exercises, often under simulated conditions of disorientation or low visibility.

Evacuation management plan

Consideration of all the various aspects of the mine when examined in the light of the previously enumerated factors should be incorporated into a mine evacuation or Self-Escape Management Plan.

The plan should be developed using the criteria established in guidelines for Queensland Safety Management Plans or the New South Wales Risk Management handbook for the Mining Industry MDG 1010.

This would provide all persons underground with the capability to reach a place of safety, recognising the difficult environmental conditions likely to be encountered following an underground incident.

Bibliography

Recommended Guidelines for Oxygen Self-Rescuers-Volume I, Underground Coal Mining, June 1981

Recommended Guidelines for Oxygen Self-Rescuers-Volume II, Appendices, June 1981

Recommended Guidelines for Oxygen Self-Rescuers-Volume III, Escape Time Studies in Underground Coal Mine, June 1983

Person Wearable SCSR Task Force, Final Report by Jeffery H. Kravitz, Chief, Mine Emergency Operations, Mine Safety and Health Administration and John G. Kovac, Supervisory Mechanical Engineer, USBM

Federal Register; May 15, 1992; Part II; 30 CFR Parts 70 and 75 Safety Standards for Underground Coal Mine Ventilation; Rule

Report of Investigations/1990; RI 9310; Probability of Making a Successful Mine Escape while wearing a self-contained Self-Rescuer - A Computer Simulation

Information Circular 9385/1994, The Emergence of Leadership in a Crisis: A Study of Group Escapes from Fire in Underground Coal Mines by Kathleen M. Kowalski, Launa G. Mallet, and Michael J. Brnich, Jr.

Physiological Responses of Miners to Emergency; Volume I, Self Contained Breathing Apparatus Stressors

Physiological Responses of Miners to Emergency, Volume II, Appendices

An Examination of Major Mine Disasters in the United States and a Historical Summary of MSHA's Mine Emergency Operations Program by Jeffery H. Kravitz

Mine Rescue and Survival, Final Report, National Academy of Engineering, 1970

Working Group Report on Respiratory Escape Apparatus and Development of an Escape Strategy DMR, New South Wales, February 1996.

Journal of 1-6 Mine Ventilation Society of South Africa – Editorial The Self Rescuers - May 1995

Chamber of Mine of South Africa - Position paper on performance and life potential of Self- Contained Self-Rescuers

European Structured EN401 - 1993 Chemical Oxygen (KO₂) escape apparatus

The introduction of self contained Self-Rescuers into the South African Mining Industry by HJM Rose - July 1988

Escape and Rescue from Mines - Approved Code of Practice and Guidance - HSE UK 1995

Deployment of self-contained self rescuers in coal mines P MacKenzie Wood et al.

Moura Task group 4 Report Qld DME/QMC 1997

Various discussion papers by NSW Underground Emergency Systems working group

Report on Overseas study into escape systems R Bancroft Qld DME 1997

Report on Overseas study into escape systems P Eade BHP 1997

COMMUNICATIONS - RESEARCH and DEVELOPMENT PROJECTS

The task group concluded that communications following underground incidents could be enhanced through several initiatives some of which required demonstration and some which required further research and development.

The communication sub-committee was:

B. Roberston (Chair), Shell Coal Pty Ltd
J. Ruble, Moranbah North
T. Hancock, Moranbah North
G. Eaton, BHP Collieries
T. Willmott, Dartbrook Mine
D. Decker, CSIRO
J. Jacka, CSIRO
R. Wischusen, AMIRA
D. Pomfret, Power Coal

The recommendations and actions were:

- Develop alert/alarm systems – options to be considered and consolidated
- Investigate “reverse PED” concept – develop research proposal
- Develop robust telephone nodes – cooperate with suppliers to demonstrate
- Test escapeway medium frequency inductive systems – trials
- Reinforce mine-wide radio networks – trials
- Demonstrate tracking – trials
- Facilitate communication between employees – evaluate options with SCSR manufacturers
- Develop distress beacons – review prototypes, develop research projects if feasible
- Establish protocols – for industry panel
- Develop vital signs monitoring – source transducers, trial

An industry committee/forum was established to examine each of these recommendations and propose action plans for implementation. The committee determined that:

- Traditional alert/alarm systems were not ideal for coal mines but that a satisfactory full time radio-based communications system would satisfy this need.
- A “through-the-earth” radio system which allowed messages to be sent from underground to surface was highly desirable and potentially feasible but required significant development. An ACARP grant was made to CSIRO Division of Radiophysics to develop such technology.
- Reinforcement of telephone and radio systems through installation of redundant links to surface via boreholes was seen as a viable strategy and trials were to be encouraged. CSIRO is developing a cellular system of low cost radio repeaters which provides improved redundancy and reliability by virtue of overlapping cells. MF inductive radio systems suffer from voice quality and range but may be usefully deployed in emergency escapeways. Suitable manufacturers should be encouraged to demonstrate capabilities.

- Tracking of personnel and equipment was commercially available but depended on network reliability. Demonstrations would be forthcoming.

It was necessary to consider how escaping persons could effectively communicate with each other when wearing SCSRs. This was an issue for consideration by manufacturers and mine managers, but should await establishment of satisfactory escape management plans and equipment.

Distress beacons were desirable and some prototypes of limited range are available overseas. The application of radio-based tracking transducers should encompass this requirement. Protocols were not required.

Vital signs transducers exist in the medical/surveillance industries and could readily be deployed underground, given robust networks.

It was observed that the underground metalliferous industry was more advanced in communications than was coal and that much could be learned from this experience.

GAS MANAGEMENT GUIDELINES

Introduction

The Underground Mines Rescue Strategy Development group selected a gas management sub-committee to look at the gas management information required in an emergency and how it is to be provided. This request was related to the implementation of Task Group 4 recommendations 8,9 and 12 (see pp 10 - 12).

8. Fixed tube bundles and gas chromatographs should be made available at all mines as the primary method of measuring post incident mine atmospheric conditions. (Plans, RandD and legislation).
9. Research into the development of robust telemetric sensors for gas analysis and other environmental parameters, over the ranges existing after incidents, should be prioritised (RandD).
12. Rescue teams should be provided with state of the art environmental monitoring equipment and on-line communications (RandD).

The gas management sub-committee had the following membership:

P Mackenzie-Wood (Chair), Mines Rescue Service, NSW
 D Kerr, Queensland Mines Rescue Brigade
 R Moreby, Dartbrook Coal
 D Cliff, Simtars
 W Allison, CFMEU, Queensland Branch
 W Price, Crinum Mine
 G Fawcett, Dept Mineral Resources, NSW

Terms of reference

1. To prepare guidance material that identifies available systems that will provide adequate information on gases for the effective and safe control of an incident.
2. To identify research and development requirements to enhance the adequacy of gas management systems in an emergency.

Availability of critical information

- Design criteria for monitoring systems
- Location of monitoring points
- Integrity of information
- Data management (software)
- Interpretation

Mines Rescue requirement

- Underground personal gas monitoring
- Communication surface to FAB team
- Environmental team to FAB

Training/competency

- Control room persons
- Monitoring system
- Refresher
- Sampling
- Boreholes

Documentation

- Records
- Management system

Matrix 1

- Comparison of monitoring systems

Matrix 2

- Location of monitoring points

OBJECTIVE:

To provide adequate information on gases during normal operations, during an incident and after an incident to enable effective and safe incident control.

Sub Element	Issues	Notes
Availability of critical information	Design criteria for monitoring systems	<ul style="list-style-type: none"> • Comparison of systems - See Matrix 1 (page 8) • Redundancy of monitoring <ul style="list-style-type: none"> - Tubes and sensors in same location • Continuity of information <ul style="list-style-type: none"> - Power backup (uninterrupted power supply - battery or generator) - Boreholes as additional sampling points - Utilisation of exploratory boreholes • Robust (surface to underground) monitoring points to enhance the integrity of post incident information <ul style="list-style-type: none"> - Fire resistant (self extinguishing) - Explosion resistant (protected, secured) - Boreholes may offer protection • Mobile monitoring systems (NUMBAT) to gain information from additional locations • Concentration ranges <ul style="list-style-type: none"> - Avoid range switching at critical concentrations eg 5% CH₄ and 15% CH₄ - High range capability - dual systems such as tube bundle and gas chromatograph eg 100% CH₄ - High range methods and standards to be maintained • Gases <ul style="list-style-type: none"> - CO, CH₄, O₂, CO₂ and velocity - essential - H₂, C₂H₄ - capability • Other information <ul style="list-style-type: none"> - Transducer for velocity, temperature and differential pressure at appropriate locations • Accuracy, reliability <ul style="list-style-type: none"> - Infrastructure to support calibration and maintenance to include documented procedures and Australian Standard, trained staff, range of calibration standards for all gases to cover all ranges Third party calibration audit, participation in post incident correlation and cross-sensitivity exercises - Consider pressure testing of tubes for leaks - Consider cross-sensitivity of IR CO analyser to CO₂, N₂O and H₂O, the CO electrochemical cell to H₂, H₂S, higher hydrocarbons and the catalytic sensor to CO, H₂, low O₂ and poisons <p>Note: N₂O has been found in the goaf of a number of collieries and is thought to originate from adjacent open cut operations and is a by-product from the use of explosives</p>

Sub Element	Issues	Notes
		<ul style="list-style-type: none"> • Response time <ul style="list-style-type: none"> - Results in real time required in ventilation splits, main returns and shaft bottom - Boreholes may improve tube bundle response Note: Lag time should be minimised at all locations • <i>Research (improvement) requirements</i> <ul style="list-style-type: none"> - <i>H₂ monitor (low and high range) and CO₂ sensors</i> - <i>Use of fibre optics for CH₄, CO, CO₂ (digital signal)</i> - <i>Wind blast pressure technology</i> - <i>Intrinsically safe gas and ventilation monitors powered from the surface</i> - <i>Intrinsically safe chromatographs</i> - <i>Longer life sensors</i> - <i>Head-up display, sensors powered from caplamp</i>
	Location of monitoring points	<ul style="list-style-type: none"> • All panel returns and bleeders • Intakes • Belt roads (drive heads) • Active goaf edges • Panel faces • Seal areas (maintain adequate records) • Upcast shaft • Surface monitoring room • See Matrix 2 for location requirements • <i>Research potential</i> <ul style="list-style-type: none"> - <i>Investigate damage to tubes and sensors (in both borehole and roadway locations) in methane explosions</i> Note: Klopperboss explosion gallery in South Africa has this capability
	Integrity of information	<ul style="list-style-type: none"> • Concentration (% , ppm), velocity, barometric and fan differential pressure <ul style="list-style-type: none"> - Recorded, trended graphically • Sampling information <ul style="list-style-type: none"> - Frequency must ensure significant information is available for trending • Air free <ul style="list-style-type: none"> - Computed, trended graphically • Ratios and indicators of spontaneous combustion <ul style="list-style-type: none"> - Computed, trended graphically • Explosibility <ul style="list-style-type: none"> - Concentration of CH₄, H₂, CO, O₂ and CO₂ need to be accurately determined - Computed, trended graphically • Alarms <ul style="list-style-type: none"> - Discriminated, altered for incident levels, passworded • Gas outlet for mobile laboratory • Archive capability • Alarm setting, calibration frequency records for audit
	Data management (software)	<ul style="list-style-type: none"> • Ease of use (user friendly) • Tailoring to suit site needs • Standard output interface for access by Incident Management Team • Gas data to stand alone (in addition to instrument readout and not to be shared with other underground information) • Network capability / exportable / transmittable to underground locations

Sub Element	Issues	Notes
		<ul style="list-style-type: none"> Fully supported by supplier Availability of external expert assistance Remote access (modem / e-mail) Remote viewing
	Interpretation	<ul style="list-style-type: none"> Availability of sufficient numbers of competent people - Experience - Qualification - Training
Mines Rescue requirement	Underground personal gas monitoring	<ul style="list-style-type: none"> Gases <ul style="list-style-type: none"> O₂, CO and total combustibles (CH₄ + H₂ + CO) on a 0-100% LEL output, CO₂, H₂S 2 multigas instruments per team Defeated or manipulated alarms and identifiable from normal mining instruments Data logging and down loading capability Protection from radio frequency interference Other information <ul style="list-style-type: none"> Temperature Relative humidity
	Communication surface - FAB - team	<ul style="list-style-type: none"> Rely on in-mine communications (telephones, DAC, PED) Personal inductive radios Multistrand aerial (carried and doubles as lifeline) <i>Research requirement</i> <ul style="list-style-type: none"> <i>To make existing communication more robust, flexible, safe to use</i> <i>Fibre optic cable for digital radio transmission, video (helmet cam)</i> <i>Reverse Ped to include transmission of gas and other environmental data</i>
	Environmental team - FAB	<ul style="list-style-type: none"> Psychrometer (temperature and humidity) Anemometer (M³/sec) Velometer (M/sec) <i>Research requirement</i> <ul style="list-style-type: none"> <i>Intrinsically safe, direct read out of temperature, humidity, velocity and quantity</i> <i>I.R. thermography</i> Sonar
Training / Competency	Control room persons	<ul style="list-style-type: none"> Underground experience at least equivalent to that required to obtain a current deputy certificate Advanced first-aid / life support Normal background levels, action trigger levels and action plans Competency in modules from an accredited course dealing with: <ul style="list-style-type: none"> Emergency escape plans, location of caches Emergency response plans Principal management hazard plans Familiarisation with underground operations Mine gases / detection / monitoring / sampling Principles of mine ventilation Spontaneous combustion Mine fires / explosions Interpretation of associated gas mixtures Communication skills

Sub Element	Issues	Notes
	Monitoring system	<ul style="list-style-type: none"> • Sufficient competent people on site to operate, calibrate and maintain system to ensure continuous relevant data is available when required and in the format required
	Refresher	<ul style="list-style-type: none"> • Industry standards • Challenge testing commensurate with frequency of exposure to procedures and technology • Simulations to review adequacy of action plans
Sampling	Boreholes	<ul style="list-style-type: none"> • Use of pre-installed boreholes • Emissions from rider seams • Effect of underground and surface pressure changes on inward / outwards breathing • Effect of stratification of gases • Difficulties with precise location of sample line end • <i>Research requirements</i> <ul style="list-style-type: none"> - <i>Better reliability of drilling location</i> - <i>Method to precisely determine the location of the end of the sample line</i>
Documentation	Records	<ul style="list-style-type: none"> • Archiving • Average for discrete samples (eg skipping to every 5th point?) • Training / competencies • Calibration / maintenance • Date of purchase / installation • Duty cards / resource list (people, materials, support)
	Management system	<ul style="list-style-type: none"> • Procedures • Roles and responsibilities • Audits • Review / upgrade to best practice

Matrix 1 – Comparison of monitoring system

System	Tube Bundle System	Sensor System	Gas Chromatography
Advantages	<ul style="list-style-type: none"> • No explosion proof instruments required • Easier maintenance • No underground power requirements • Wide range of gases • Instruments can be calibrated on the surface • Readily attach additional instruments, mobile laboratory or gas chromatograph 	<ul style="list-style-type: none"> • Results in real time • Long distances are possible with some types • Sensor failure is immediately recognised 	<ul style="list-style-type: none"> • Complete analysis • No cross sensitivity • Capable of measuring hydrogen • Capable of measuring ethylene and higher hydrocarbons • Wide measuring range
Disadvantages	<ul style="list-style-type: none"> • Results not in real time • Leaks are not immediately apparent • Condensation in tubes • Faults not immediately apparent • Tubes may be damaged in an explosion • Cross sensitivity of CO IR cell 	<ul style="list-style-type: none"> • High maintenance • Limited carbon monoxide sensor range (0.2%) • Limited sensors (limited for carbon dioxide / none for hydrogen) • Poisoning of methane sensor • In situ calibration • Cross sensitivity of CO sensor • Loss of power (eg > 1.25% methane) • Limited sensor life (1-2 years) • Unsuitable in low oxygen atmospheres (behind seals) • Impedance loss in cables can occur with some types 	<ul style="list-style-type: none"> • Relatively slow speed of analysis with some systems • High maintenance • Complex controls • Requires expert attention • Regular calibration • High CH₄ concentrations may interfere with low level CO measurements • Requires discrete samples

Matrix 2 – Location of monitoring points

	M/Sec	CH ₄ %	CO ₂ %	COppm	O ₂ %	H ₂ ppm and % C ₂ H ₄ ppm
Panel faces	Sensor only	Sensor only		Sensor only		
Active goaf edges	Sensor only	Tube only	Tube only	Tube only	Tube only	Tube/discrete sample
Sealed areas		Tube only	Tube only	Tube only	Tube only	Tube/discrete sample
Belt roads Drive Head	Sensor only	Sensor (Drive Head)		Sensor		
Intakes	Sensor only	✓	✓	✓	✓	
Panel returns	Sensor only	✓	✓	✓	✓	Tube/discrete sample
U/C Shaft	Sensor only	✓	✓	✓	✓	
Surface monitoring Room		Tube	Tube	Tube	Tube	

✓

- Tube and sensor required

AIDED RESCUE

Introduction

The issues relevant to Aided Rescue from underground mines have been examined to look at the equipment, systems, training and research projects that need to be considered. Recommendations and guidelines have been formulated with reference to Task Group 4 recommendations 1, 10, 11,12,13,18,19,20. The Aided Rescue sub-committee included

A. Sellars (Chair), Queensland Mines Rescue
M. Downs, BHP Coal
C. Mallett, CSIRO
J. Tapp, CFMEU NSW
B. Lyne, DME Qld

Terms of reference

- To prepare guidance material that identifies available systems and their limitations so that adequate provision may be considered in the design of mines or the development of a mines Hazard Management Plan.
- To identify research and development requirements on refuge chambers, microseismic detection systems, large diameter drilling and rescue emergency vehicles.

Refuge chambers used in underground mining

General background

The use of Refuge Chambers as a critical part of an underground rescue strategy is applied in both coal and metalliferous mines in the Republic of South Africa (RSA). There are also limited numbers of refuge chambers in use in coal mines in Australia and the United States of America, these being apparently less integrated into an overall escape strategy.

It is worthwhile noting that the South Africans have "operational" experience in the use of such chambers.

Discussions with Australian industry personnel who have recently undertaken a study tour of overseas mines and mining safety and research establishments, indicates that the concept of the rescue chamber is embodied in both statutory and operation aspects of South African mines.

It must be stressed that the Rescue Chamber concept is a part of an overall strategy involving self contained breathing apparatus, guidance systems, site infrastructure, chamber provisions and recovery methods. The Refuge Chamber is not considered a "stand alone" item.

Well developed management schemes are in place in the RSA, covering chamber inspections, placement of chambers relative to working faces, chamber facilities/provisions, associated infrastructure and training/practice schedules.

There are two basic forms of rescue chamber, these being either a portable chamber, or a static chamber, built in and limited to, a particular site in the mine. In Australia, a portable chamber design is marketed by MSA, whilst information from the RSA indicates the development of a relatively sophisticated portable design is reasonably advanced.

Static chambers are of myriad designs, each particular design being tailored to specific sites or applications. Experience in South Africa indicates that chambers should be built in "blind ends", ie not in redundant cut-throughs or between ventilation splits.

It is plausible to envisage a variety of construction methods being acceptable in the case of a static chamber, encompassing steel bulkheads, grout walls, block walls, etc.

Key points of overall strategy

The use of refuge chambers is predicted on the basis that:

- emergency egress to the surface is either prevented or is relatively more dangerous.
- entry to the refuge chamber can be achieved in emergency conditions.
- personnel can be sustained in the chamber pending rescue.
- personnel recovery from the chamber can be effected in a timely manner, either by stabilising external mine conditions to suit self egress, or by specialist teams equipped with self-contained breathing apparatus.

Each of the strategic factors above prompts a set of conditions or requirements that must be in place for the refuge chamber principle to be effective. The concept of the refuge chamber is unlikely to work in isolation.

System requirements

Significant training will be needed to gain behavioural acceptance of the refuge chamber as a "muster point" in case of an emergency, rather than "bolting for the surface".

Guidance systems such as cone/lanyard ropes and audio visual systems are required to enable the refuge chamber to be reached under conditions of extremely poor visibility, disorientation, confusion and shock.

Chamber location guidance will be a key feature, to promote the ease of access to personnel with limited travelling capabilities due to capacity limitations with self-contained breathing apparatus.

Refuge chambers will need to be capable of affording protection against explosions, fire and inertisation, both to withstand an initial incident and be available to survivors, and to protect the "inmates" against subsequent events.

The design parameters for refuge chambers therefore need to address:

- supply of fresh air;
- air-lock arrangements;
- water and food supplies;
- communication;
- fire and explosion protection;
- lighting ; and
- retrieval of personnel.

An inspection regime for the overall system will be required to maintain all facilities in effective working condition.

Recovery strategies for personnel in a refuge chamber will be required and needs to address the possibility of atmospheric stabilisation by inertisation prior to mine-re-entry by rescue teams.

Personnel recovery can be envisaged in three main ways, these being;

- through the mine to the entry points under relatively normal conditions, either accompanied or unassisted;

- through the mine to the entry points under breathing apparatus and assisted by a rescue team on foot, or with a manned vehicle or with a remotely controlled vehicle;
- through a large diameter borehole directly to the surface.

Industry developments - Australia

There are instances of refuge chambers in use in Australia, the most notable being the Capcoal Central example. This chamber is a static chamber, built in a reasonably central proximity to a number of working areas and featuring a large diameter borehole (mini vent shaft) in close proximity for emergency egress.

The use of personal self-contained self rescuer breathing apparatus has recently become an imminent requirement in Queensland, and this together with a "cache" system to provide actively promoted for immediate usage in underground coal mines.

A research submission is currently being considered that if successfully funded will ultimately deliver a rescue vehicle. Further work is also planned in the area of inertisation, which with the recent purchase of the GAG 3 jet equipment, provides a strong inertisation capability for Australian mines.

An associated development in the Australian industry that is most pertinent to the overall safety of underground coal mines is the adoption of standards applicable to all structural ventilation devices. These standards and the resultant improved structures will enhance the possibility of personnel survival in the event of an explosion, such that the provision of post-explosion facilities may become more relevant.

It should be recognised that the adoption of refuge chambers and associated strategies is not an alternative to "escapeways" but that the refuge chamber may also have some benefit in the instance of a major mine fire.

MICROSEISMIC DETECTION SYSTEMS

Introduction

In the US, MSHA maintains a microseismic monitoring facility which can be deployed on the surface, and can locate signals generated by miners striking the roof and floor of the mine. There is also a portable system which could be taken into emergency zones to help locate people or significant events. These form part of the emergency response facilities of MSHA. The MSHA surface system is described and the potential for application of microseismic emergency monitoring in Australia is discussed.

The MSHA seismic location system

A seismic location system was developed by the USBM in the early 1980s to locate workers trapped underground. A truck with geophysical monitoring equipment was assembled, and a standardised routine for trapped workers devised. The deployment procedures and elements in the system are:

1. A truck with geophone arrays and recording equipment is deployed on the surface above a mine where workers are trapped. Up to seven arrays are used and the geophones located with GPS.
2. Trapped workers are notified that the monitoring system is in place by firing three explosive charges.
3. Signals are then generated by trapped workers striking the roof and floor of the mine 10 times in succession. If no response is received from the surface, the 10 blows are to be repeated every 15 minutes.
4. When a signal from the miners is received at the surface, and the source located, 5 shots are fired to indicated to the underground workers that their signals have been received and that they are located.

Experimental systems were reported by Shope et al (1982) and it was claimed the system was effective to 600m. An operational unit is maintained in a state of readiness by the Mine Safety and Health Administration at Pittsburgh Research Centre, Brucetown. It is reported that the current system can detect signals at a range of 450m and can locate the signal source to within 30m. The unit is tested in field trials 3 times a year.

Miners are issued with a hat sticker by MSHA which describes the procedures to follow if they find themselves trapped underground.

Although the MSHA system is directed to the precise location of trapped workers underground, it also performs an extremely important function of confirming that trapped workers are alive. This is of great value to the rescue operation even if their precise locality cannot be determined.

MICROSEISMIC APPLICATION FOR AUSTRALIA

Surface systems

The MSHA equipment is entirely surface based. The technique detects the characteristic signal made by the miner's blows in the mine, and locates the signal source by triangulation of the wave paths detected by arrays on the surface. This utilises source location routines commonly used in seismology. Arrays of geophones are used to reduce extraneous surface seismic sources, so the signal initiated by the underground miners is enhanced. A surface system does not require any prior development of infrastructure by the mine site.

Requirements for an effective surface system include:

Access to the surface

This can be restricted by rugged terrain, cultural developments or overlying water bodies

Propagation of signals

An essential requirement for an effective surface system is that the underground signals must propagate to the surface. The American experience indicates that signals can be detected up to 450m in some strata conditions. Strata may attenuate or divert signals so they cannot reach the surface. Microseismic experiments in Australian mines have encountered difficulties monitoring signals from depth, and causal factors include

- source too deep;
- strata structurally disrupted;
- layered high and low velocity beds;
- rapid signal attenuation in goaf and gassy units; and
- overlying Tertiary and Quaternary sediments and volcanics.

From the Australian experience 450m detection distances is expected to represent the best possible performance, and this would only be in the most favourable circumstances. Areas with thick Tertiary and Quaternary sediments at the surface would prevent any surface detection of signals from working depths.

Potential conditions affecting signal detection in Australia coalfields include:

	Negatives	Positives
Southern coalfield	Mines generally too deep Surface access	Solid rock
Western Coalfield	Surface access	Solid rock Some shallower workings
Newcastle	Surface access Strong and weak layers	Some shallower workings
Hunter Valley	Localised surficial deposits	Access generally good Shallower workings
Bowen Basin	Extensive surficial deposits	Shallower workings Access generally good

An analysis on a mine by mine basis would show that some locations potentially have excellent conditions for surface detection, and others are unlikely to be successful sites at the depths of current mining.

Deployable systems

A surface microseismic system would have to be maintained at the ready if it was to be used in emergencies. There would have to be a standing capacity and emergency access to trained operators. This would logically be a shared industry facility rather than the responsibility of any operator. The microseismic techniques and equipment required are well known and a number of Australian consultants and agencies could provide the technical requirements.

Borehole systems

Some of the difficulties with surface systems in Australia could be overcome by using geophones installed in boreholes. These can be placed in competent rock near to the worked seams, to reduce propagation distances and to avoid wave paths travelling through problem materials.

Many exploration boreholes are drilled around underground developments, and it would be simple and inexpensive to install a geophone during grouting of the holes. These geophones could be used during emergencies.

The position of boreholes is based on other specific needs so it is unlikely that a mine would be able to set up a network which would allow triangulation coverage of all underground areas. Most mines however, would get a coverage of boreholes which would provide at least one monitoring point throughout the workings. This would at least allow confirmation that trapped workers were alive, and indicate that their location was within the detection area of the activated geophone. If triangulation and location detection were not required, each borehole would need only a basic monitoring device to record the geophone signals, so that any repeated seismic waves generated by the miners could be identified. These units could be deployed along with other mine rescue service activities, and would not require specialised personnel.

Small portable microseismic systems

Small portable microseismic systems can be transported and operated in any emergency situation. MSHA has such a unit which has also been used at natural disasters such as earthquakes. These units use well known technology and commercial groups could either provide equipment or a service.

Introducing the technology in Australia

The lack of any local experience discourages the implementation of microseismic technology for rescue operations in Australia. This could be overcome by undertaking demonstrations of surface and borehole configurations by using existing geophone installations and conventional seismic survey instrumentation.

Success in these trials could lead on to the provision of seismic personal location service for emergencies, which could include the following elements:

- adoption of routine geophone installation in boreholes;
- establishing local mine performance;
- training of workers to use the system; and
- training and equipping of mines rescue services.

SUMMARY

Microseismic location from the surface, of underground miners hammering, is demonstrated by MSHA in the US, for distances up to 450m at 30m accuracy.

Only a small proportion of Australian mines are believed to be amenable to surface detection methods because of unfavourable access problems or geological conditions.

Mines with favourable conditions could do local tests, and there are a number of Australian groups with the technical capability to advise mines.

Geophones installed in mine boreholes could provide a good coverage of most mines and provide a way to verify miners were still alive, and their general location. A simple instrument would need to be developed to monitor the geophones, and could be deployed by mine staff or mines rescue brigades.

Widespread take up by the Australian mining industry is dependent on successful demonstration of the technique.

References

SHOPE, S., DURKIN, J., and GREENFIELD R. 1982 Finding and communication with trapped miners. Bureau of Mines Information Circular / 1982 No 8907, 49-78.

BANCROFT R., 1997 Overseas study tour to investigate self rescue systems and underground escape strategies. Department of Mines and Energy Queensland Internal Report.

Large diameter drilling

Status report is currently being compiled on the current worldwide best practice (published Q1 1998)

Rescue emergency vehicle

A large amount of effort and research development has gone into the first concept machine called the NUMBAT over this decade. Trials have been undertaken over the last 3 years at selected mines in New South Wales and Queensland. All of these trials have proved certain parts of the technology and directed other developments in line with current thinking in mines rescue response from the industry.

The current vehicle has proved that it is suitable in some instance for Emergency Response to determine environmental conditions (gas monitoring, atmospheric conditions) with video response as a tool to provide a low risk technical exploratory capability before rescue or recovery decisions are made.

During 1997 the changes in approach to rescue and recovery techniques defined shortfalls to our overall response, which had relied largely on luck and hope.

The changes now focussed on a risk approach where we could control the conditions, accurately assess the environmental changes and minimise the consequential damage to other persons.

Legislative changes in both NSW and Qld to the use of hazard management, Management Plans, self rescuers and systems, self escape training and in Queensland the provision of (2) GAG engines for mine inertisation have changed our "Rescue" response.

The provision of portable refuges fixed or and the probable inertisation of a mine to effectively minimise the risk of uncontrolled explosions means that a rescue response vehicle needs to be developed. Both NSW and Qld cross industry groups are working together to develop a vehicle capable of high speed access with life support systems for up to 15 people that can operate in an inert atmosphere. Much of the original NUMBAT technology will be directly transferable with the main focus on the cabin design, life support and engine systems. This RandD project will be reported on later in 1998.

MINES RESCUE STRATEGY DEVELOPMENT

Introduction incident management

The Underground Mines Rescue Strategy Development group selected a committee to look at the information, equipment and other criteria needed in an emergency to manage an incident. The issues were related to the implementation of Task Group 4 recommendations 15, 16, 17.

- 15 Capability to model ventilation and the mine environment following an incident
- 16 Integrated emergency preparedness guidelines for mine operators and emergency services, common to both Qld and NSW
- 17 Development of computer-based emergency decision support system for incident management and training

The incident management sub-committee included:

Gibson	MRSNSW	(Chairman)
English	QDME	(Secretary)
Garland	QMC/North Goonyella	
Gillies	University of Qld	
Hendricks	NSWMC/BHP Collieries	
Hutchings	QMRB	
Stothard	CFMEU	

R15 Ventilation and environmental modelling

Ventilation modelling to include:

- modelling of post incident mine ventilation and atmosphere to be a required element of Mine Safety Management Plans;
- development of learned ventilation and fire control responses for different incident scenarios and locations, pre determined for each mine, with plans prepared and personnel trained in appropriate action plans.

- determining the explosibility of atmospheres;
- distillation profiles for the coal in each mine to be determined and incorporated into models; models to interface with standard mine planning packages and kept up to date;

R15 Progress Report

- Survey of industry ventilation modelling;

Of 18 mines using MINVENT 17 operated by consultants;

Of mines using VENTSIM only 2 use consultants;

5 other mines use 3 other modelling systems;

10 (smaller) mines currently do not model; and

No contact/responses from 9 mines

- VENTSIM

Windows based system designed and supported in Australia; and

User friendly, favoured by experienced mine ventilation engineers.

- MINVENT

Currently favoured by consultants, perhaps because of better printing facilities; and

Limited support available.

- Post-Incident ventilation/environmental monitoring
- Two post-incident ventilation/environmental monitoring systems identified

M-FIRE, developed by MSHA for simulation of mine fires; and

POZAR, developed by Polish Ventilation Academy to enable mines to simulate mine fire effects in multi-face/seam mines and evaluate intervention strategies.

- M-FIRE

- Public domain software, limited adoption and development, only validated once

- POZAR

- Routinely adopted by Polish mines, intervention evaluations accepted by Polish authorities;

Tried at Collinsville, and to undergo further evaluation at North Goonyella; and

Current marketing strategy limits access.

R15 - Selection Matrix for Industry system

- User friendly (Windows based);
- Capable of being broadly adopted as industry standard;
- Acceptable to new generation Ventilation Officer;
- Integrate with mine planning/survey systems;
- Capable of modelling dynamic situations; and
- Capable of integrating real time P, Q, and T data.

R15 - Recommendations Being Considered

- Support concept of statutory Ventilation Officer and development of appropriate competencies
- Competencies to include ventilation modelling in static and dynamic post-incident applications
- User friendly ventilation software should be adopted as industry standard
- Develop capability to integrate real time P, Q, T

Develop integrated industry network and expert system for post-incident monitoring and evaluation

R16 emergency preparedness Guidelines

Guidelines should address:

- Roles and responsibilities of mine management and emergency services in an emergency; and
- Consolidation and integration of emergency response procedures developed through principal hazard management plans

Development of a common training program as a joint pre-requisite for mine managers and undermanagers accreditation in Qld and NSW

Development, maintenance and assessment of appropriate competencies.

R16 progress report

- MRBNSW has developed Guidelines for mines rescue organisations and personnel, currently being evaluated by QMRS

Sub-Committee to develop Guidelines for operators, with initial draft due end-November 1997

R 17 computer-based emergency decision support system

- Incident Management enhanced by decision support system that:
 - provides strategic information on the mine and the incident;
 - provides an analysis of the developing situation;
 - presents prioritised options available; and
 - provides training system.

R17 PROGRESS REPORT

- ECAS system developed by ACIRL under NERDDC funding in 1989-90 requires significant enhancement and more user friendly platform;
- Literature search underway to identify other possible systems; and
- Systems utilised by armed forces and emergency services to be investigated

CSIRO trial of Virtual Reality Modelling System including mine emergency applications supported